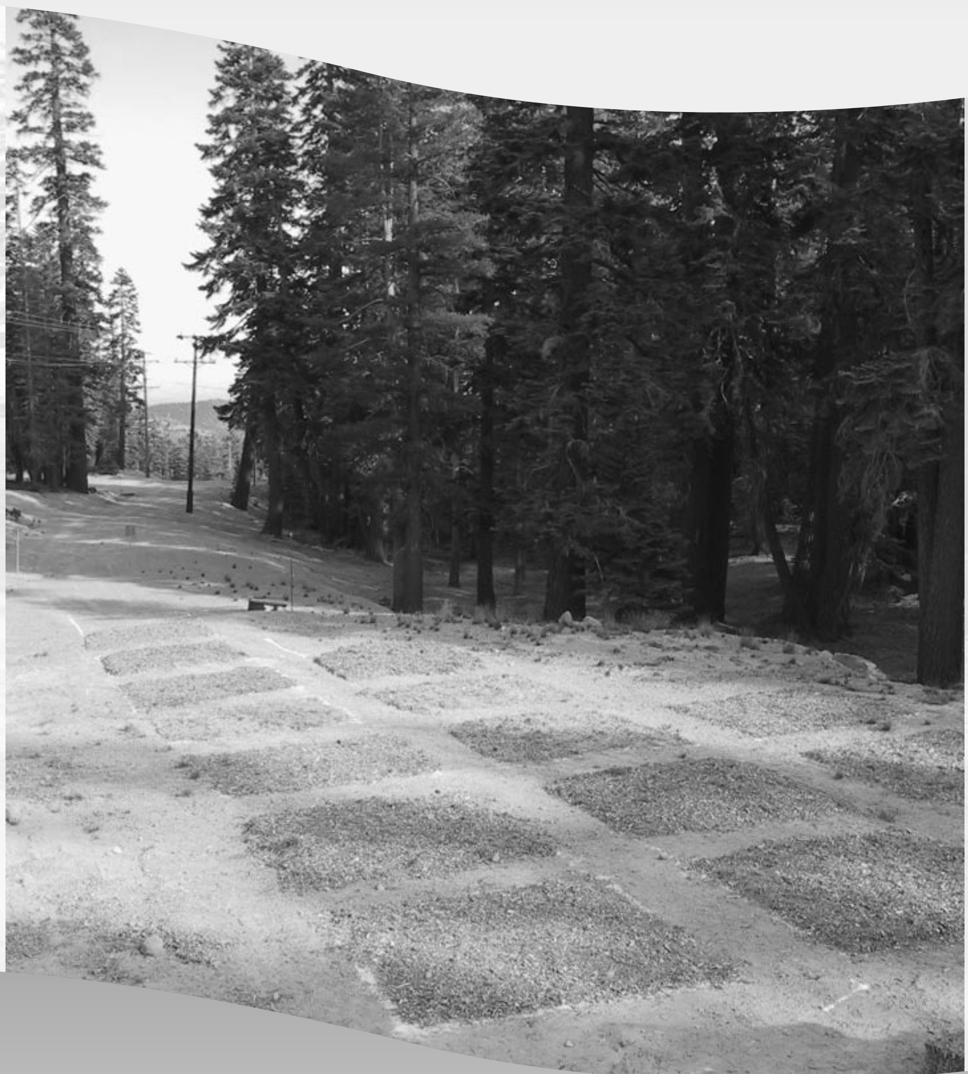
The California Alpine Resort Environmental Cooperative

presents

The Sediment Source Control Handbook

Preliminary Version – April 2005



Written by Michael Hogan,

Integrated Environmental Restoration Services

for The Sierra Business Council

in Cooperation with

The Lahontan Regional Water Quality Control Board

"All ethics so far evolved rest upon a single premise: that the individual is a member of a community of interdependent parts. His instincts prompt him to compete for his place in that community, but his ethics prompt him also to cooperate (perhaps in order that there may be a place to compete for). The land ethic simply enlarges the boundaries of the community to include soils, water, plants and animals or collectively: the land."

(Leopold 1949)

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Acknowledgements

The vision for the California Alpine Resort Environmental Cooperative (CAREC) emerged from ongoing discussions between Michael Hogan of Integrated Environmental Restoration Services, Martin Goldberg of the Lahontan Regional Water Quality Control Board and ski resort personnel. Many tensions over erosion issues between regulatory and ski area managers were due to the lack of good information on how best to control sediment in highly disturbed alpine areas. The idea to work together collaboratively to develop field trials was supported early by Harold Singer of the Lahontan Regional Water Quality Control Board, Amy Horne of the Sierra Business Council and a number of ski areas including Northstar-at Tahoe, Mammoth Mountain, Heavenly Lake Tahoe, and Alpine Meadows. With initial support from the Lahontan Regional Water Quality Control Board, a pilot program was launched to set up field plots and learn from different types of erosion-control treatments.

CAREC emerged from this pilot program as a collaborative partnership that includes representatives from ski resorts, Lahontan Regional Water Quality Control Board, US Forest Service, Tahoe Regional Planning Agency, consulting firms, Integrated Environmental Restoration Services and the Sierra Business Council. Time, resources, and technical input are all provided by the members plus outside 'experts' such as the Natural Resource Conservation Service (NRCS), the Nevada Resource Conservation District, and University of California Davis.

The key people who have worked throughout the pilot phase to help advance this program, install field trials, actively respond to earlier drafts of these pages, and commit to learning together about erosion control processes in disturbed alpine areas include:

Paquita Bath, Vice President, Sierra Business Council

Lou Cayer, Heavenly Ski Resort

George Cella, Lahontan Regional Water Quality Control Board

Todd Ellsworth, Ecologist, Inyo National Forest

Alex Fabbro, Planning Department, Mammoth Mountain Ski Area

Naomi Garcia, Environmental Scientist, TEAM Engineering & Management, Inc.

Martin Goldberg, Environmental Scientist, Lahontan Regional Water Quality Control Board

Melanie Greene, Scientist, Parsons Water and Infrastructure

Larry Heywood, Snow and Ski Safety Consultant

Michael Hogan, President, Integrated Environmental Restoration Services

Amy Horne, Research Director, Sierra Business Council

Eric Knudson, Squaw Valley USA

John Loomis, Director of Operations, Northstar-at-Tahoe

Erin Lutrick, Hydrologist, Inyo National Forest

Clifford Mann, Director of Mountain Maintenance, Mammoth Mountain Ski Area

Cadie Olsen, Trinity Environmental

Michael Schlaffman, Winter Sports Specialist, Inyo National Forest

Randy Westmoreland, Eastside Watershed Program Manager, U.S. Forest Service

Many thanks also to Karyn Erickson of the Sierra Business Council for the layout of this 2005 preliminary version of the Sediment Source Control Handbook.

Finally, developing collaborative programs that directly affect key businesses and water quality, requires a high degree of personal and institutional commitment. We acknowledge the commitment of all the CAREC team members to share their experiences, invest in experiments, and improve our understanding of sediment source control in ski areas throughout the Sierra Nevada.

I am grateful for the opportunity to work with this collaborative and serve as editor for this handbook. We look forward to continued cooperation on behalf of the Sierra Nevada.

Paquita Bath
Vice President
Sierra Business Council

Introduction to The Sediment Source Control Handbook

Sediment is a major water pollutant in the Western United States today. Wherever development takes place, disturbed areas are prone to sediment movement. Ski resorts are no exception. Large cut and fill, steep graded ski runs, can pose a serious threat to nearby waterways. Unfortunately, effective methods to control erosion for drastically disturbed alpine areas have not been well researched or documented. Despite a long list of 'BMPs', or recommended 'best management practices', attempts to stabilize disturbed alpine areas continue to produce inconsistent results.

To date, there has been little effort to develop a systematic approach — with specific goals, documented procedures, and ongoing monitoring — to control erosion in ski resorts. Projects are undertaken in a trial and error fashion, sometimes resulting in successful outcomes, and sometimes producing less than optimal results. While there is a broad range of knowledge across resorts, information sharing has been limited.

The California Alpine Resort Environmental Cooperative (CAREC) came together in 2003 to develop a process for planning and implementing erosion control projects and to experiment, through field plots, with various approaches to control sediment on site and thus reduce erosion. The purpose of the partnership is to use field plots to develop on-the-ground practices to better manage erosion and maximize sediment source control on ski area properties. The underlying philosophy is that a collaborative approach between land managers, field practitioners and regulators is the best way to develop an effective, functional and workable set of practices that parties can adapt to fit their needs while greatly enhancing their ability to control sediment in ski areas.

The group meets two to three times a year to share field trial results and challenges. CAREC uses an adaptive management process to plan, implement, and measure erosion control projects and then share information with other practitioners and regulatory personnel. This 2005 Handbook expresses the preliminary approaches and findings of an ongoing program to document cost effective and measurable improvements in sediment source control practices in Sierra ski resorts. The Handbook is made up of three sections:

Part I: Guiding Principles – provides an adaptive management approach to planning and implementing erosion control projects;

Part II: Technical Notes – describes treatment approaches as a starting point for developing better practices, procedures, and monitoring protocols.

Part III: Literature Review – references appropriate information for planners, practitioners, monitoring personnel and scientists involved in upland sediment source control projects.

Thanks to the State Water Resources Control Board, this pilot project will grow to incorporate field trails in at least six different ski resorts and substantial monitoring of sediment source control. An updated version of the Sediment Source Control Handbook, will incorporate monitoring results and CAREC's improved ability to control sediment in 2008.

Sierra Business Council

The Sierra Business Council (SBC) is the only membership-based regional organization devoted to securing the social, natural, and financial health of the incomparable Sierra Nevada. Founded in 1994, the award-winning SBC achieves its mission through leading-edge research & publications, on-the-ground programs and fee-for-service, and grass roots membership and community networking. Business, government, non-profit, and civic leaders use SBC to meet, share-ideas, gain access to resources and expertise, and put plans into action. Partnering with local communities, and in partnerships such as the California Alpine Resort Environmental Cooperative (CAREC), the Sierra Business Council helps communities plan for and achieve their visions for the future.

SBC is entering its second decade as an award-winning, regional business organization. In response to the enormous challenges facing the region, the Sierra Business Council helps Sierra communities work together to steer the region's economy, environment and communities in directions that ensure long-term prosperity. Recent accomplishments include:

- Being chosen by Governor Arnold Schwarzenegger for his prestigious 2004 Environmental and Economic Leadership Award.
- Developing the bipartisan coalition behind the landmark Sierra Nevada Conservancy bill, signed by the Governor, which invests in our natural, cultural, and historic assets.
- Training business and civic leaders in our world-class Sierra Leadership Seminar to improve individual professional skills while enhancing the civic infrastructure of our region.
- Securing funding for the Town of Truckee to explore development of a railyard brownfield to extend the vibrant downtown;
- Convening hundreds of Sierra business and civic leaders to address critical topics such as affordable housing, fostering creative communities, and the state of the Sierra.
- Publishing award-winning research documents like the *Sierra Nevada Wealth Index*, *Planning for Prosperity*, and *Investing for Prosperity* that are used every day to build sustainable wealth in our region.
- Partnering with the Edward Lowe Foundation to provide our members business and entrepreneurial resources plus a new SBC e-News & On-Line Networking tool.
- Developing a partnership of ranchers and conservationists to maintain ranching as a fundamental part of the Sierra's economy and landscape – conserving over 30,000 acres of working ranchland in the Sierra Valley;

SBC is proud to provide programs, research and documentation, such as the *Sediment Source Control Handbook,* that can stimulate residents and decision makers to work together to ensure that the Sierra Nevada remains one of the most desirable places to live, grow a business, and raise a family. The CAREC partnership will be expanded between 2005 and 2008 to ensure that our knowledge and understanding of sediment source control on steep alpine slopes continues to improve.

***For more information on the Sierra Business Council or to become a member, please visit www.sbcouncil.org*.**

The California Alpine Resort Environmental Cooperative

Sediment Source Control Handbook Part I

Guiding Principles

Preliminary Version – APRIL 2005

Written by Michael Hogan,
Integrated Environmental Restoration Services
for The Sierra Business Council
in Cooperation with
The Lahontan Regional Water Quality Control Board

Sediment Source Control Handbook Part I

Guiding Principles

Table of Contents

Introduction to the Guiding Principles

The California Alpine Resort Environmental Cooperative (CAREC) came together in 2003 to develop a process for planning and implementing erosion control projects and to experiment, through field plots, with various approaches to control sediment on site. Part I of the Sediment Source Control Handbook, consists of sixteen Guiding Principles for sediment source control in ski resorts in the Sierra Nevada. The full Handbook, also includes Technical Notes and a Literature Review that provide additional information and complement the Guiding Principles. The Guiding Principles are split into three sections: 1) Planning; 2) Implementation; and 3) Monitoring, to cover assessment, follow-up and information sharing.

Each Guiding Principle follows a general format for consistency and accessibility:

Goal: Describes the purpose of the Guiding Principle.

Description: Describes in greater detail, the Guiding Principle itself.

Example: One or more examples of the Guiding Principle. In some cases, the example also contains a solution or positive example of an application that supports the Guiding Principle. In other cases, the example describes a less than optimal situation that a particular Guiding Principle is meant to address.

Solution: In cases where the example describes a sub-optimal situation, the solution section describes an ideal application of that Guiding Principle.

Technical Notes: This section is listed when there are Technical Notes that provide more in-depth input for the Guiding Principle. Technical Notes describe treatment strategies that can be used to implement particular Guiding Principles. These Technical Notes are to be improved, upgraded and enhanced over time, as we learn from our on-the-ground applications.

Additional Suggestions: Describes any additional information, suggestions, etc., related to this Guiding Principle.

For references cited please see the Reference List in the Literature Review (Handbook Part III).

FRAMING THE PROGRAM: THE ADAPTIVE MANAGEMENT MODEL

The concept of adaptive management has been applied for centuries under a number of different names. Physical engineers have used this approach since the first structure or bridge was constructed to continually learn from mistakes and successes and improve designs. Adaptive management has a dual nature.

First, adaptive management is a philosophical approach toward resource management that acknowledges that we do not completely understand the system that we are dealing with. It acknowledges that we will proceed with a project or program using existing information while we gather the knowledge that we lack.

Second, adaptive management is a structured decision-making process that includes the following components, usually in stepwise and cyclical fashion:

- Articulate project goals, outcome or success criteria
- Collect existing knowledge and practices relative to achieving the goals
- Identify information gaps and related research needs
- Develop a strategy and apply knowledge and relevant practices towards achieving the clear goals
- Develop a clearly-defined and defensible monitoring program to determine whether the goals are being achieved
- Negotiate a pre-defined management response if the goals are not met.
- Reassess and improve practices and reconsider the goals or outcomes.

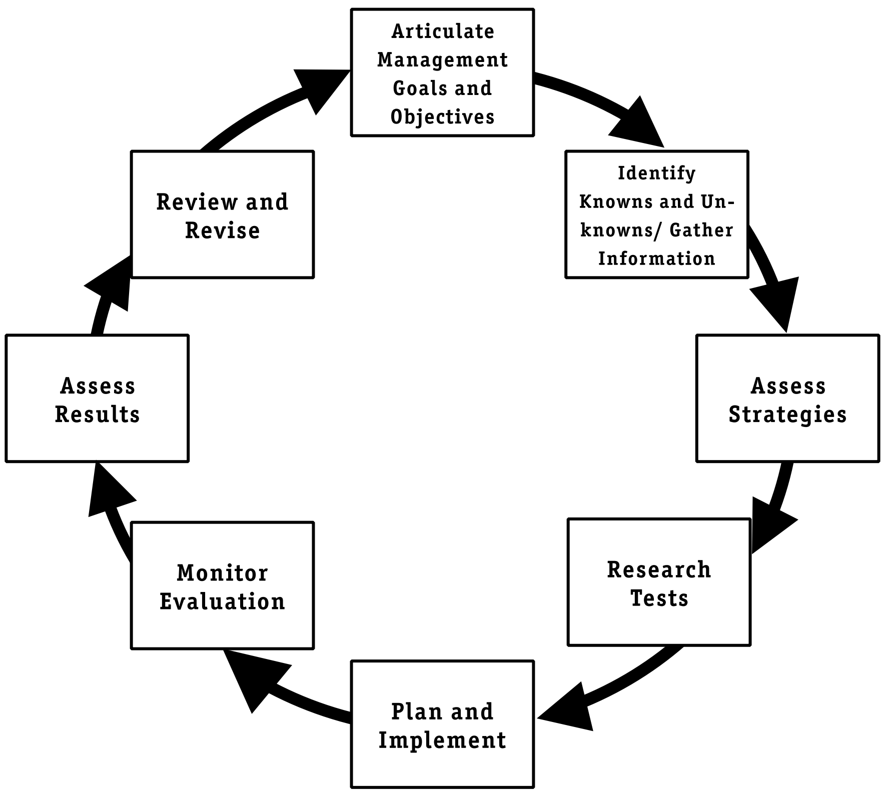


Figure 1: The Adaptive Management Model

The CAREC partnership chose to use an adaptive management model as its framework (Ringold, Alegria, et al. 1996; Elzinga, Salzer, et al. 1998; Chiras 1990). Figure 1 represents the adaptive management model graphically. It is used throughout the document to illustrate where a particular step or practice falls within this model.

Section One: Planning

GUIDING PRINCIPLE 1: IDENTIFY THE NEED FOR ACTION AND/OR THE PROBLEM

Goal: To clearly understand both the need, or 'trigger', for taking action and the specific problem(s) being addressed.

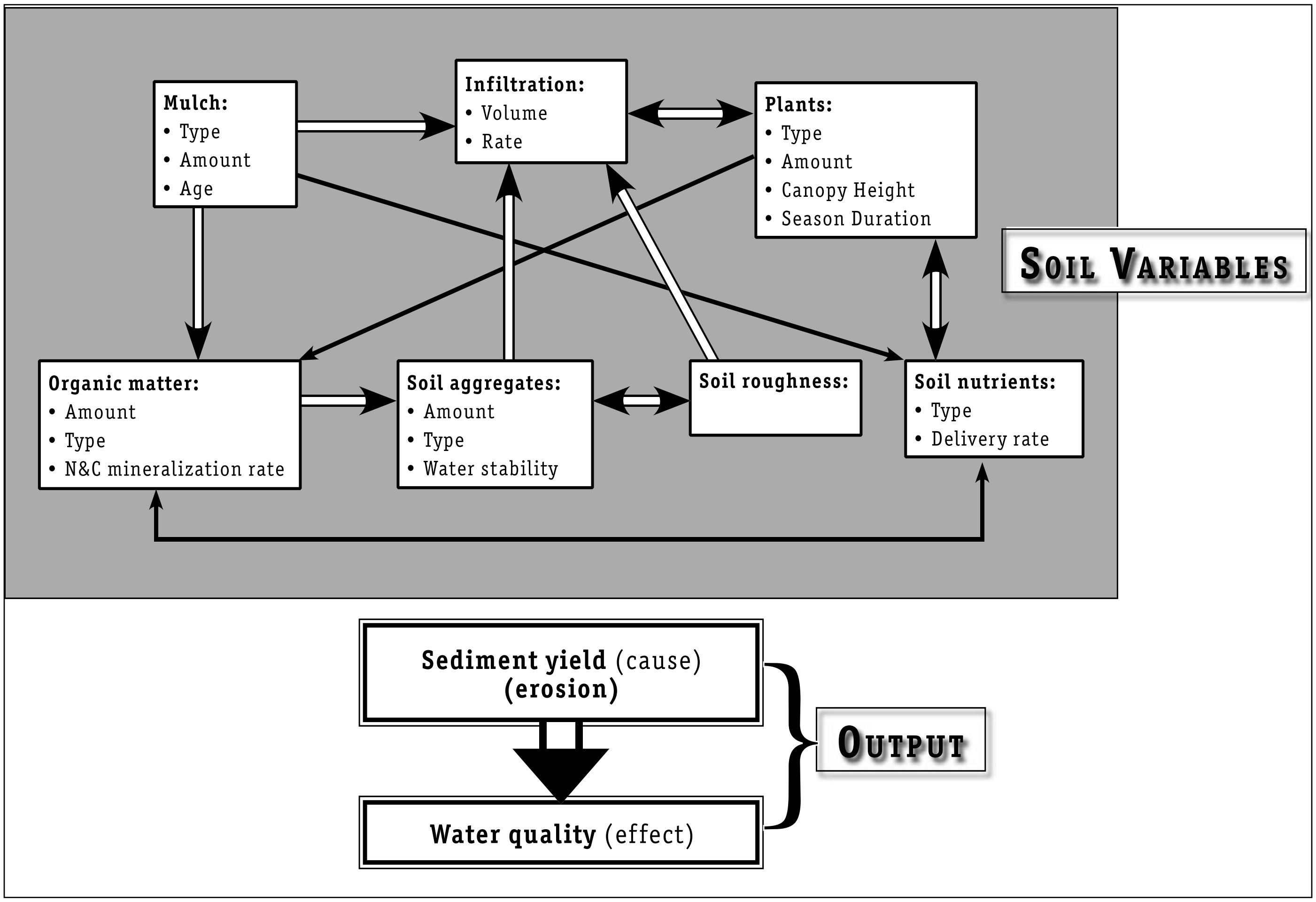
Description: The first step is to: 1) decide or understand why action is being taken; and then 2) identify what the problem is. The need for action is often straightforward. Identifying the nature of the problem is often more difficult. Action is sometimes taken without understanding the true nature or scale of the problem and thus may result in solutions that address the symptom, but don't directly resolve the source of the problem.

- Action may be triggered by identification of a water quality/erosion problem, for instance rilling of a ski run or a mass failure (landslide). It may be triggered by regulatory agency request or any number of other reasons.
- When the need for action is understood, it is critically important to understand the nature of the problem as completely as possible.
- It may take time to fully understand the nature of the problem. Time spent understanding the problem(s) early in the planning process usually pays off because there is a much higher probability of focusing resources (people, equipment and money) on the causes of the problem, rather than the symptoms.

Example: A ski run is heavily rilled. Both management and the local USFS representative identify the rilling as a problem. The area is re-seeded, mulched and irrigated. Vegetation is established. However, after a summer thundershower, rilling is again noted.

Solution: Rilling was a problem. A breached set of 5 waterbars above the area of concern indicated a more complex source of the problem. In this case, the lack of water infiltration in the soil across the entire ski run resulted in the surface runoff. The runoff was not stopped by either the vegetative cover or the waterbars. This area will probably need to have the soil treated so that infiltration rates are increased and surface runoff is decreased.

Additional Suggestions: The erosion model below may provide a good starting point or checklist to help identify which elements of the erosion control process may be failing.



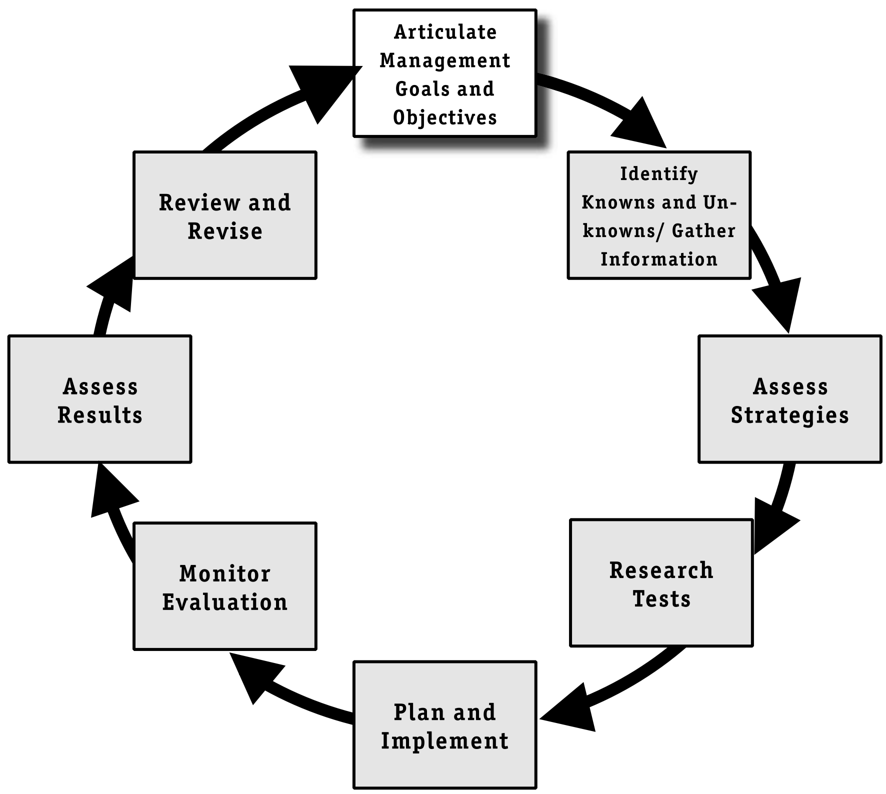
Erosion Model

GUIDING PRINCIPLE 2: STATE PROJECT GOALS AND OBJECTIVES[1]

Goal: The goals of this section are twofold:

1) Goals: to define in general terms, and as inclusively as possible, the desired project outcome;

2) Objectives: to define, in specific and measurable terms, desired project outcomes based on stated goals.



Description: Developing and defining project goals allows the project planner to define the intended outcomes. Project goals and objectives are reference points that define the rest of the project. These goals and objectives will ideally be linked directly to addressing the problem(s)/need for actions that were identified in Guiding Principle 1.

Goals and objectives refer to similar concepts but differ in detail. That is, goals are broad, general and 'non-specific' statements such as "controlling erosion on the GS Run." Objectives are the more specific

[1] The terms 'Goals' and 'Objectives' can be confusing. For the purpose of this document, we use terminology that has been adapted from Stanley, John T. (2004) 'Ecological Restoration and Watershed Stewardship Planning Terminology', Tahoe Regional Planning Authority.

If you don't know where you're going; any old road will get you there.

Will Rogers

measurable manifestation of that goal such as "developing minimum infiltration rates of 1 inch per hour" or "developing a native grass stand on the GS Ski run of 25% plant cover in three years."

Goals should be:

- Clearly stated and direct
- General and non-specific
- Inclusive (sediment control AND wildlife habitat maximization)
- Flexible enough to persist over time

Objectives should be:

- Specific
- Measurable
- Realistic and attainable (physically and economically)
- Directly related to the problem
- Time specific (state when and how long?)

Success criteria are specific measurable elements directly tied to project goals and objectives (*see Guiding Principle 3*).

Example: While goals are relatively non-specific, they can be problematic if not clearly related to the source of the problem. For instance, a goal such as "Revegetate the GS Slope" is vague and may not be the appropriate solution for sediment source control in that area. Poorly framed goals and objectives are difficult or impossible to measure, thus not contributing to an improved understanding of sediment source control.

Solution:

Goals: To control erosion [on an eroding ski run] through soil treatment and native vegetation community establishment.

Objectives: To establish an infiltration rate on the GS Run to levels similar to (within 10% of) a native forested area of similar slope and aspect in the vicinity, and to establish a native plant community of 25% vegetative cover within three years.

Additional suggestions: The process of defining goals and objectives can be simple and involve only a couple of individuals. With larger projects, it may involve a great many stakeholders. Generally, involving as many interested parties as possible, as soon as possible, in the planning process minimizes unforeseen roadblocks later in the process.

GUIDING PRINCIPLE 3: DEFINE SUCCESS

Goal: To define success in quantitative terms wherever possible so that the project outcome (at a specific point or points in time) can be clearly measured and understood.

Description: Success is defined by quantitative or at least clearly identifiable specific criteria. Criteria should reflect whether the project goals and objectives have been met. It should be as clear as possible whether the success criteria listed are direct measurements, such as 'visible rills' or indirect measurements such as cone penetrometer measurements as an indication of whether soil is too compacted to infiltrate water.

Success criteria must be achievable and practical. These criteria will generally include a number of elements, for instance, plant and mulch cover, soil nutrient status, soil density (cone penetrometer measurement), and visible soil movement.

Example: A project is being planned whose goals include both erosion control and aesthetic or visual impact improvements. Success criteria may include plant cover, mulch cover, adequate soil nutrients, no signs of visible erosion, low soil density, native flowering shrubs and forbs and no bare areas.

Solution: Each of these elements will be assigned a number and quantifiable objectives. Based on the differing objectives, each project will probably have different, site and project specific success criteria.

Additional suggestions: Success criteria often represent indirect measurements of performance. Cummings (2003, 4:S79-S82) and others have suggested that success be linked to functional elements such as hydrologic function (infiltration, water storage, etc.), nutrient cycling (soil nutrients, plant potential for cycling, etc.) and energy capture (plant and microbial biomass production and carbon processing), rather than just measuring or assessing the above ground plant community. This change in emphasis may be much more effective in indicating long-term project success.

Management response: A management response describes actions that are to be taken when success criteria are not met. These actions can be listed on a success criteria matrix. This process places the responsibility for action in the hands of the land manager and typically does not require regulatory agency oversight. At this time, there are no set standards for management responses. However, a proactive and agreed-upon set of management responses can maximize the efficiency of both agency and land managers, making interactions more straightforward and positive since follow up is agreed upon in advance and not suddenly enforced through crisis regulations.

GUIDING PRINCIPLE 4: ASSEMBLE THE PROJECT TEAM

Goal: To identify and assemble appropriate planning and implementation personnel that will assure the best project outcome.

Description: An effective plan requires personnel with an understanding of: **a)** the nature of the problem; **b)** how to fix the problem; and **c)** how to effectively carry out the plan in the field. Project team make-up and size vary greatly from project to project and from area to area. Simple projects can be managed with a small team while larger, more complex projects, may require a broad range of expertise. An effective team will include, at a minimum, a team leader/project coordinator and a person or persons with expertise directly relevant to the problem areas. (A list of potential team members is included in the sidebar.)

4.1: Assemble a Team Leader/Project Coordinator

The most basic element of a team structure is the team leader, project coordinator and/or contact person. In a simple project, this person may also have the expertise to plan and implement the project. In more complex projects, this person will be responsible for assembling and coordinating the team and should be the central contact point for both the team and the stakeholders.

4.2: Assemble a Team with Appropriate Expertise

Appropriate expertise is critical. A civil engineer will not usually have the expertise to address sediment source control issues and a botanist will not usually be able to design a retaining wall. The nature of the problem or project will drive the expertise needed.

Example 1 - Small scale: A ski run has been identified as not meeting specific success criteria. It shows evidence of rilling, a large, bare area and two failed waterbars. The mountain manager and the Regional Water Board representative discover these conditions during a routine walk-through. They agree that the mountain manager will provide the Regional Board with a plan to repair the problems and then, upon review, implement the plan.

The mountain manager contacts the erosion control manager on staff who has 15 years practical experience and several courses in erosion, botany, soil processes, etc., and asks her to develop a plan. This plan is developed, submitted to the Regional Water Board and approved. The erosion control manager then gives direction to the 3-person crew to carry out the plan as written.

Functionally, this 'team' is made up of 5 people: the project leader/coordinator (mountain manager), the planner/implementation director (erosion control manager) and the implementation team (3- person crew).

Example 2 - Large scale: A new ski run was defined in the Ski Area Master Plan of 1985. Funding has been acquired to construct this run, which skirts a wetland. Management has begun planning this year's construction schedule. In this case, the ski area planning director is assigned project coordination. This project will be large and complex and will require planning, permitting, wetland regulation, civil engineering, biology, soil, revegetation/ erosion control and other expertise. Planning will be challenging to coordinate. Further, part of the team may include community or interest group members who have general or specific concerns (such as intrusion into potential wetland habitat) that could present roadblocks later in the project if not addressed up front. The project coordinator will choose some or all of the expertise from the sidebar list, as appropriate.

Additional suggestions: Assembling and coordinating an effective team is time consuming and challenging. However, a great deal of project experience shows that when done properly, this process can ultimately lead to a more effective project on the ground and can minimize challenges and/or roadblocks to project implementation.

Potential Expertise/ Team Members

Planning

Ski area managers

Project manager(s)/coordinator

Planners

Technical

Erosion control specialist

Revegetation specialist/Botanist

Geomorphologist

Watershed specialist, watershed hydrologist

Restoration specialist

Engineer

Wetland specialist

Ski run construction specialist

Ski area implementation personnel

Regulatory

USFS

Water Board staff

County staff (engineering and/or permitting)

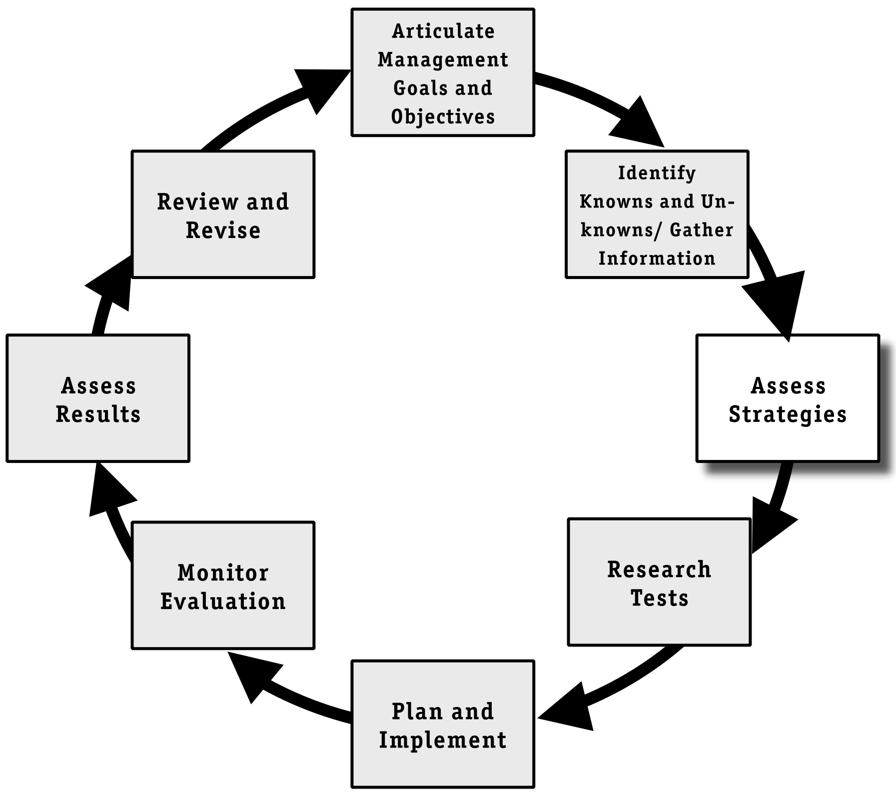
Stakeholders

Note: a team may include some or all of the above listed members. Some 'members' may have a limited role. For instance, county staff may simply advise what permits will be needed and will then review the plans to make sure they adhere to county ordinances. Implementation personnel should review plans to ensure they are feasible. Engineers and erosion control specialists may be involved all through the process. Further, individuals may have two or more areas of expertise, for instance erosion control, revegetation and watershed hydrology.

GUIDING PRINCIPLE 5: ASSESS STRATEGIES FOR A SITE SPECIFIC IMPLEMENTATION PLAN

Goal: To develop a sediment source control implementation plan that is based on specific site conditions and that targets clearly identified outcomes.

Description: Develop a plan that addresses existing site conditions, and defines a process for meeting the desired project goals, objectives and success criteria. The following list details steps and considerations for developing that plan.



5.1 Assess site conditions

Document existing conditions in order to determine next steps and measure results.

Example: Cone penetrometer readings indicate how compacted the soil is, in turn, providing guidance on whether tilling or other soil physical treatment will be required. Similarly, a nutrient analysis of soil samples will indicate the potential for plant growth and the need for amendments to rebuild the soil.

5.2 Choose a reference site

Assessment of a suitable reference site presents a 'standard' or reference to aim for.

Example: Soil nutrient analysis of a nearby reference site which supports adequate native vegetation will suggest the appropriate level of nutrients needed on the ski slope. Vegetation analysis of a reference site will suggest what vegetation community can actually be supported in this environment. Reference sites may be a native site or a previously treated site that is performing according to success criteria.

5.3 Develop a plan based on the two previous steps

The project plan is based on site conditions and information found in nearby reference sites. This allows the plan to be site specific and achievable.

Example: a project site is analyzed for both soil density and soil nutrients. The project site has a soil density maximum of 500 psi (pressure per square inch) to a depth of 6 inches at which point the penetrometer stops. Total soil organic matter is 0.7% and total N is 350lbs/ac. The reference site, a revegetated site nearby with a high level of plant cover, has penetrometer readings of 275 psi to a depth of 16 inches. Soil nutrient analysis indicates 3.75% organic matter and 1800lbs/ac of total N. This baseline clearly indicates that soil tilling and organic matter amendment will be required on the project site.

5.4 Maintain natural conditions to the greatest extent possible

It is important to maintain 'natural' hydrologic, nutrient cycling, topographic and other physical conditions to the greatest extent possible.

Example: During construction, drainages will ideally be left unaltered. Topsoil will be left in place or salvaged and replaced. Where one or more of these conditions is altered, the plan should re-create the natural conditions to the greatest extent possible. For example, if a drainage is intercepted and/or altered during the construction of a ski run, a new drainage should be constructed that mimics the pre-disturbance drainage as much as possible. A road constructed across a hillside interrupts the dispersed surface runoff. The road should be outsloped and drainage should go across the road to encourage ongoing dispersion. Capturing the hillside runoff, by contrast, would concentrate water and build up a great deal of erosive energy.

5.5 Consider potential alternative treatments

More than one potential treatment should be considered. Treatment alternatives can be developed from the Technical Notes or other appropriate, field-tested tools. Time, intensity of the problem, and available resources will define which tools would be most effective.

Example 1: A steep slope is eroding and depositing sediment near a stream. Alternative treatments may include silt fencing, straw bales, full soil-restoration treatment or mulching. Given the proximity to the stream and the temporary duration of some of the potential alternatives, the full soil-restoration treatment is likely to be the most effective, though most costly of the treatments.

Example 2: A nearly flat area erodes during high intensity rainfall events. This area is 500yds from the nearest creek and runoff must travel through a great deal of vegetation to reach the creek bank. Alternatives include full soil-restoration treatment, mulching, tilling of wood chips, straw bale barriers, or a silt fence. Given the distance to water, the flatness of the slope, the easy availability of wood chips, and the fact that budget constraints exist (it's a ski area), the project manager chooses to till wood chips into the soil to increase infiltration and mulch the soil surface with no further treatment. If this treatment meets the success criteria (no measurable erosion off site), this would be an effective and cost-saving alternative.

5.6 Incorporate tests where information gaps exist

When choosing treatments, planners will encounter information gaps with regard to materials, treatments, time frames etc. Wherever possible, tests can be overlaid on treatments to help answer those questions and fill information gaps. In this way, each project adds tour knowledge base and furthers future project outcomes.

Example: A recent erosion control conference presentation showed that a specific fabric significantly reduced erosion during year one of a large project in South Carolina. A steep road cut near Mogul Lift has been eroding and management has decided to address the problem. The budget is too small to apply fabric to the entire area. You are also not sure how the fabric will respond to snow over the long-term and want to test it in local conditions. You are able to afford 500ft of the fabric, which you apply to one portion of the project. In the subsequent 3 seasons (the time portion of the 'success criteria') you monitor the entire site, comparing the fabric area to the standard treatment, looking for signs of erosion and measuring plant growth for differences. This test was inexpensive and provides valuable information on whether the fabric contributed to the success criteria and its usefulness in high alpine areas.

5.7 Choose appropriate treatments

The treatment alternative(s) that are chosen should be adequate to meet project goals and objectives, should be field tested, and should be aligned with project budget parameters.

Example: In the previous two examples, if a silt fence had been chosen, it is unlikely that effective project outcome would be achieved. Silt fences are temporary structures, have not proven effective in snow areas, and fail to address root problems. CAREC is committed to avoid these 'do something, even if it doesn't work' treatments, by rigorously testing alternative approaches.

5.8 Identify and address potential threats to project success

Impacts on treated sites such as post-project vehicle or foot traffic, skier impacts in areas with low snow, lift tower access, or potential ATV traffic need to be considered and addressed. If impacts cannot be eliminated, protections must be put into place if overall project goals are to be met.

Technical Note 1 and 2: Assessing Site Conditions

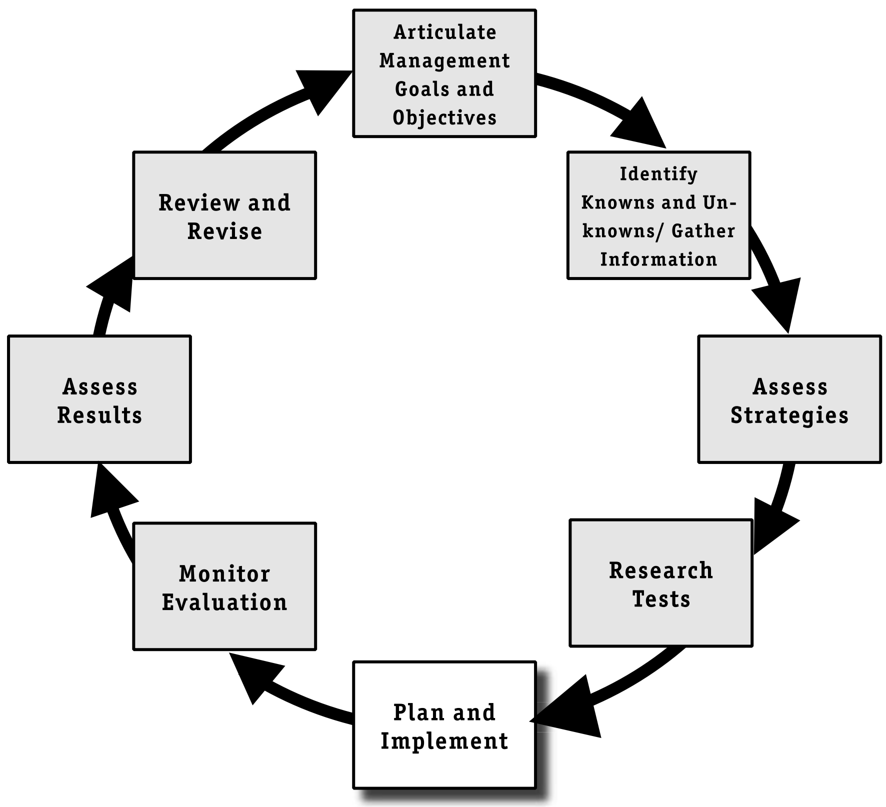
Section Two: Implementation

Section Overview: This section describes processes that will assure maximum success when applying sediment control techniques in the field. The Guiding Principles in this section assume that a carefully constructed plan has been developed.

GUIDING PRINCIPLE 6: TRAIN STAFF AND ASSOCIATED PERSONNEL

Goal: To increase the level of awareness and understanding of the sediment source control program for all ski area personnel from implementers to resort personnel uninvolved in project treatment activities. This Guiding Principle is for internal resort protocols and practices.

Description: Training is critical to raise awareness of sediment source control as well as to ensure no post-treatment disturbances disrupt the projects. Implementation staff need to be fully versed in project goals and strategies. General resort personnel must understand travel restrictions and ways to avoid inadvertently harming treated areas. Strategies need to be developed and shared regarding outside impacts, such as by mountain bikes, ATVs and so on. With full staff support and understanding, treatment sites will be better managed. Further, when personnel understand erosion processes and goals, they can help spot, and possibly repair, small problems such as water bar breaks or clogged culverts.



Example 1: A small ski area maintenance crew is spreading compost on the Downhill Run so that it can be tilled in and revegetated. They haul the compost to the run and push it over the side, 'covering' the run as told. Unfortunately, the compost is 9 inches deep at the top of the run and 1 inch deep lower down. Remedying this mistake costs an additional four hours for three people.

Solution: A 15-minute training session that explains the soil restoration process and why compost needs to be spread evenly for tilling would help ensure the crew distributes the compost effectively the first time.

Example 2: The Lower Concourse area near lift 500 has just been recontoured and replanted along an old seldom used, lift access road. To access a new area designed for summer concert activities, Joe Lifto, a long-time lift mechanic, drives straight across the treated area in the approximate location of the old road. This ruins the treatment, and requires new soil tilling to get rid of the 4-wheel drive ruts, plus the expense and time needed to recontour and replant.

Solution: A memo sent to all personnel, communication with department heads and a directive from the Operations Manager indicating that all treatment areas are strictly off limits. The memo details the accepted driving areas. A system of personal accountability will help achieve these goals.

Additional suggestions: This proactive step, while requiring more up-front time, is essential for managing treatment sites to stabilize soils. A regular communication process from sediment source control personnel to the rest of the staff can help to meet goals and gain widespread support for the program when they understand the purpose and strategies being implemented on the treatment sites.

GUIDING PRINCIPLE 7: OVERSEE AND DOCUMENT ACTIVITIES

Goal: To oversee implementation of erosion control activities and to document installation of treatment sites in the form of 'as-builts'. Precise documentation allows for useful ongoing monitoring to learn from the various treatments.

Description: Implementation oversight, sometimes called 'implementation monitoring', assures that project plans and specifications are applied as written and intended. This step is also used to make adjustments to specifications in the field, where plans are not feasible as written, or where some other method may work better.

During implementation oversight, notes, drawings and photographs that explain what was done, how it was done, when, who was involved, any changes to the original plans and ideas for alterations or method improvement should be documented. The erosion control manager has to ensure that implementation is tracked, however delegated, and then check for accuracy and a consistent format across treated areas.

Example: Oversight: A manager instructs his crew to seed the Uphill Down Run after a snowmaking line is installed. The manager is not able to supervise the project, which requires coordination between the snowmaking installers and the reveg crew. The snowmaking line is installed and backfilled and the reveg crew hydroseeds the area. The following day, equipment movement tears up the hydroseeded area.

Solution: Oversight: Better coordination or direct oversight of this project would have resulted in only part of the area being treated. The crew was unaware that lateral lines were being installed and therefore hydroseeded areas that were to be torn up. Better coordination would have saved 5 hours of labor and $700 of seed and fertilizer.

Example: Documenting: Erosion control treatment is installed along the length of a full ski run, with two test areas along one side where a new type of compost and two seed mixes are used. The project manager doesn't record or photograph the process nor indicate the location of the test plots on a map. She is sure she will remember this simple layout and will record it before winter begins. However, she forgets due to the onset of an early winter. During the winter, she takes a beach break and disappears over the Bermuda Triangle, never returning to work. The following season, no one knows which treatment went where or how much compost was applied.

Solution: Documenting: The project manager uses the Site Assessment Data Sheet (Technical Note 2) and added additional information about the treatment. . The following season, her replacement knows exactly what was done, where it was done, how deep tilling was done and the exact seed mix. He also has photos of the process so he can better understand how things were implemented.

Technical Note 2: Site Assessment Data Sheet

Additional suggestions: Project oversight can be the difference between success and failure. Project documentation and tracking can be the difference between knowing why a project did well and having no idea why it succeeded or failed. Both elements take extra time but significantly reduce wasted resources and frustration.

GUIDING PRINCIPLE 8: MAINTAIN, MAXIMIZE AND/OR RE-ESTABLISH HYDROLOGIC FUNCTION

Goal: To maintain or create a situation where hydrologic function, especially surface hydrology, is stable and does not degrade the watershed.

Description: Erosion is influenced by interrupted and improperly designed surface water patterns on ski runs, roads and elsewhere. Planning for and implementing surface hydrology and flow patterns is critical whenever new developments disturb the soil. The most effective approach is to leave existing flow patterns undisturbed and design around them. Where that is not possible, a high level of practical planning is needed to address and accommodate existing and potential water flows.

Example 1: An existing road carries water during spring runoff, resulting in severe rilling and erosion to a nearby stream. A plan is developed to place waterbars along the road to direct water into existing roadside vegetation before it builds up volume and velocity. However, as water is redirected, it erodes fragile soil beneath the existing roadside vegetation, causing even more erosion and destabilizing the hill slope.

Solution: This is an insidious and difficult issue. Some combination of settling/distribution areas, rock lined, vegetated outfalls or other elements should be considered. When waterbars are installed, they must be appropriately placed with frequent spacing, and be properly constructed and maintained. They also must be able to outfall into a stable area and/or outfall structure.

Example 2: A new ski run is cut down a steep north-facing slope that holds snow late into the spring. This slope was logged over 40 years ago and remnants of 4 logging roads that transected the slope still existed. The ski run was cut and successfully revegetated. Five years later, large, 3-foot deep headcuts and trenches can be seen from across the valley during the summer. Large amounts of sediment were deposited into the nearby creek, reducing summer flows and essentially ruining the little remaining fish habitat.

Solutions: Two elements of this situation contributed to the problem. The most obvious is the capture of flows from the 4 roads by the ski run. This contributed to high levels of surface flows. In this case, the roads were eliminated, surfaces restored, and the road capture of runoff water eliminated. A related and more subtle issue is that, in the construction of ski runs, a great deal of compaction occurs, particularly in high-clay soils. Compaction results in very low infiltration rates and greatly increases sheet flow, which also contributes to sediment movement throughout the entire ski run. This type of erosion is difficult or impossible to see until rills and gullies begin to form. The solution was to add organic matter to the soil surface and till the run in strips across the run face to maximize infiltration. This process effectively reduced surface flow by 600%, thus reducing or in many cases, eliminating erosion.

Additional suggestions: The design for effective hydrologic function related to roads, ski runs and other disturbance areas needs a great deal of further investigation. Standard BMPs do not tend to deal with this issue in a systemic manner.

GUIDING PRINCIPLE 9: MAXIMIZE SOIL FUNCTION

Goal: To create a soil physical and biological environment that optimizes water infiltration and plant and soil microbial communities.

Description: Soil is the foundation of terrestrial ecosystems. Soil physical and biological status will determine, to a large extent, how erosion-resistant a site is. Maximizing soil function is done through:

- soil sampling to determine soil density, soil nutrient content and cycling potential;
- soil amendment (organic matter) addition where suggested by soil samples; and
- soil tilling where density is high and/or where organic matter is to be incorporated into the profile.

Mulch is also extremely important in soil function (*See Guiding Principle 10*).

Example: Two adjacent ski runs are constructed. The planning team has just attended a seminar where it was suggested that tilling and organic matter amendment is important in controlling erosion on ski runs. They instructed the maintenance department to try these two techniques. On one run, they spread three inches of compost and left everything else as they had always done. On the other run, they tilled the soil to twelve inches and then applied standard seed mix, fertilizer and straw mulch. Two years later, they received a notice of violation from the State Water Control Board for excess phosphorus and nitrate in the nearby creek and for excess sediment in another creek.

Solution: In applying compost to the first area, there were two problems: 1) they didn't know what the actual nutrient status was. It turned out that there were adequate nutrients in the soil and that compost wasn't really needed. By not tilling and by adding excess nutrients, what was added ran off of the compacted surface and into the creek, causing a large algae bloom. In the other case, the soil was tilled but due to low organic matter in the soil, it recompacted within two seasons, resulting in a large amount of surface flow and a 10 yd^2 mass movement that placed a large amount of sediment in the creek. The solution would have been to sample the soil, add compost where NEEDED, and till both runs. This would have resulted in increased infiltration, increased soil root penetration and more sustainably stable ski runs.

Technical Note 3: Soil Physical Preparation

Additional suggestions: Our understanding of soil processes and soil amendments for steep wildland areas is in its infancy. Information gaps on soil function present a range of opportunities for testing.

GUIDING PRINCIPLE 10: MULCH AND SURFACE PROTECTION

Goal: To provide surface cover and protection as the first line of defense against erosive forces.

Description: Surface cover or mulch, is a critical and, perhaps, the most cost effective sediment source control treatment. Mulches vary widely in both form and function and include wood fiber mulch, straw, wood chips, pine needles and erosion control blankets. Mulch should be put on heavily enough to control surface erosion and will ideally be long lasting.

Mulches are known to provide some or all of the following benefits:

- interception of raindrop energy;
- reduction of surface water flow velocities, reducing erosive forces and increasing infiltration;
- filtration of sediment entrained in surface water flows;
- long-term, slow-release nutrient source;
- infiltration by increasing soil biologic activity/soil aggregation;
- buffering of soil temperatures;
- reduction of evaporation from soil; and
- aesthetic benefits

Example: Mulches vary widely. Bonded fiber matrix is a wood fiber mulch with polyester fabrics added. Wood chips or tub grindings are popular and pine needles have gained wide acceptance as a mulch that also results in a natural looking surface after application.

Solution: Mulch should be linked to the intention of the project and the service life of the mulch. If a short-term (1-2 year) mulch such as straw is used, consideration should be given as to whether the soil and plants established in that time frame will survive without mulch or need additional applications.

Additional suggestions: Mulch use has changed a great deal in the past ten years with more emphasis being placed on long-lasting mulches. A great deal of the garbage waste stream in a ski area during certain times of the year may consist of materials that can be used as mulch. More work needs to be done in this area.

GUIDING PRINCIPLE 11: VEGETATION

Goal: To choose the appropriate plant materials to advance project goals.

Description: While vegetation was once considered the primary defense against erosion, the CAREC literature review and recent research suggests that vegetation, while important, is one component of an overall system of erosion control elements.

Vegetation considerations are complex and knowledge of native plant species is limited. Considerations for choosing plant material will include some or all of the following:

- Is the plant species easy to establish?
- Is the plant species appropriate for the site?
- If planted from seedlings, what is the survival rate?
- Does the plant mixture require additional irrigation and if so, has that irrigation been planned for?
- Does the species regenerate itself?
- Is it an indigenous native species?
- Is the plant material of choice available and in sufficient quantities?
- Does the chosen material fit budget realities?
- Can the species survive in a ski run situation, especially with low snow pack?
- Does the species fit with the desired aesthetic?
- Does the species stabilize the soil?

Example: A steep-cut slope was revegetated with expensive native shrub seedlings. Planting was difficult and required additional irrigation. Within 2 months of installation, a late summer shower delivered 1.25 inches of precipitation in less than 45 minutes. Following the thundershower, the entire slope was covered with rills. Approximately 1/3 of the plantings were washed away.

Solution: Habitat or aesthetic goals were confused with soil stabilization goals. In this case, a grass mixture with infrequent irrigation during the first summer would have provided the soil with surface protection and soil strength though root structure. Native seedlings are often less effective than grass for soil stabilization in the early period. A good seeding with grass and a robust mulch cover (assuming adequate infiltration) would have provided protection to this area. Seedings could then have been incorporated in subsequent years to grow into a long-term role for stabilizing the slope with deeper root penetration.

Technical Note 6: Plant Materials

Additional suggestions: Little is know about many native species. Planting and tracking survival rates of different native species on each project would be a valuable input into our learning process.

GUIDING PRINCIPLE 12: PROTECT PROJECT AREA FROM FURTHER DISTURBANCE

Goal: To reduce or eliminate post-project disturbance to maximize treatment benefits.

Description: Once an area has been treated, additional disturbance is likely to re-compact the soil, reduce infiltration, and destroy vegetation. Protection against post-treatment disturbance is critically important for project success.

Example 1: Bubba's run had just been completed and treated. Vegetation was just beginning to sprout when Bubba himself, a much loved and now retired staff member, decided to take a quad trip to see what his run looked like in the summer. He took the summer road to the top of the run and in a fit of pride and exuberance, headed straight down the run. The irrigation technician/ snowmaker, had just finished watering the run so Bubba's trip down was a bit slippery, requiring some skidding. The next spring, two large rills/gullies were visible from run top to bottom.

Solution: GP 6 discusses the importance of staff training. However, not all staff, and certainly not the general public, know to avoid treated areas. In dealing with both staff and visitors, physical blockades and warnings enforce the message. Blocking previous access points with boulders, logs or ribbon, and possibly signs, would have eliminated a large and growing sediment delivery problem on Bubba's run.

Example 2: A large, disturbed area has been treated/revegetated next to a mountain bike trail. The Cross Country World Cup is to be held in a week and a large number of participants are in town to practice. The bike rally staff checks the course and requests that the maintenance crew fence off the treated area. However, the crew gets sidetracked on another project and believes they still have 5 days until the race. When the lifts open for practice runs, the bikers, seeing an open area with a pine needle cover, use that area for warm ups and as a short cut to the lift. By the time the fencing is put in place, the entire area, loose in the first place, is completely destroyed.

Solution: When the soil-vegetation treatment was completed, fencing should have been put in place, thus eliminating confusion. Further, signs would be put in place along the edge of the project explaining that this is a sensitive area and should not be traveled on.

Additional suggestions: Where all other restoration elements are in place, post-treatment disturbance is often the one factor that causes project failure. Early planning for how to avoid disturbance, pays off.

Section Three: Monitoring, Assessment, Follow-up and Information Sharing

Section Overview: This section describes practices that monitor the effectiveness of site treatments. Monitoring or assessment informs the project proponents, regulators and other stakeholders, how the project is performing. Monitoring can also suggest where additional treatment may be required before small problems become large. This information can directly help improve the design of future projects.

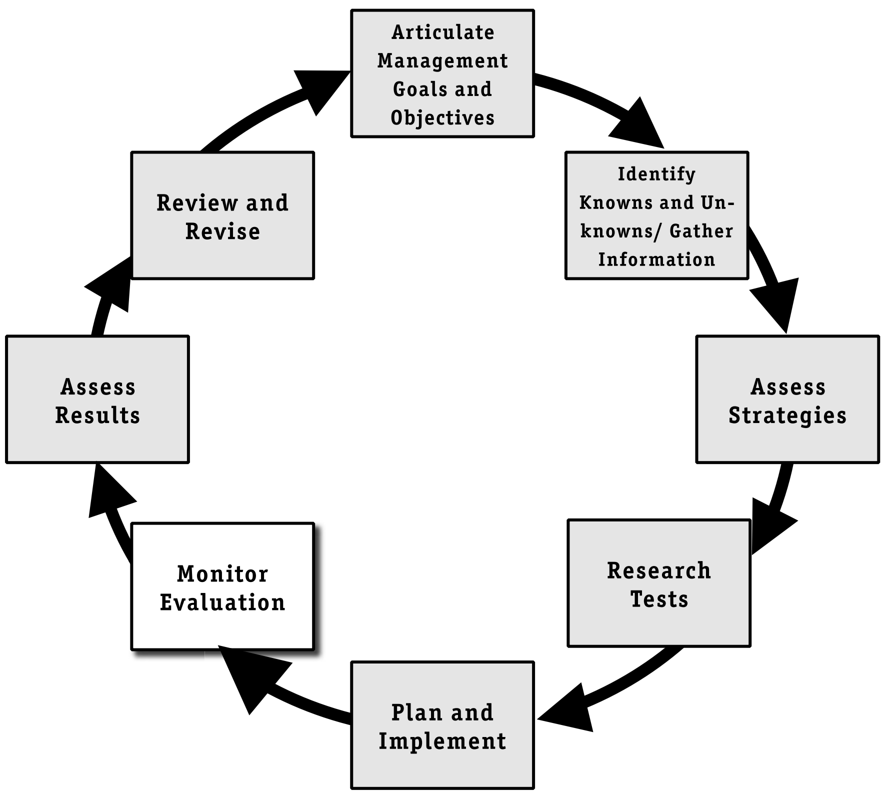
GUIDING PRINCIPLE 13: PERFORMANCE MONITORING

Goal: To assess project performance in a quantifiable manner against project success criteria and to gather information for a number of subsequent uses, as described in Guiding Principles 14, 15, and 16.

Description: There are three main types of monitoring:

- Compliance monitoring (meeting regulatory, especially water quality standards)
- Implementation monitoring (was the project implemented as planned. This type of monitoring is discussed in GP 7)
- Performance monitoring (how the project is *functioning* or *performing*)

It is this third type of monitoring that we are discussing here.



Monitoring should gather *useful* and *usable* information. Information or data should be linked to success criteria and should be quantifiable to the greatest extent possible. When quantified, information is less prone to interpretation and thus argument. Visual interpretation is generally not very reliable. The monitoring helps the reviewer understand, not only if success criteria are met, but also how the project is functioning.

Monitoring may include any or all of the following, depending on project needs and requirements:

- Soil nutrients analysis
- Soil density (penetrometer measurement)
- Plant and mulch cover (cover point)
- Visible erosion
- Weedy species
- Bare areas
- Drainage and/or hillslope hydrology functions

Performance monitoring will determine whether success criteria are met and trigger management responses (see GP 3) when they are not met.

Example: A project is constructed on the Lower Left Out run of Inner Mongolia. Success criteria list, among other things, a requirement that no bare areas of greater that 15 square yards shall exist in the treatment area and that, of the 300 seedlings planted, a survival rate of 50% would be expected. Upon inspection, a large bare area was noticed as a result of a small surface slump. Further, in the nearby area planted with seedlings, only 40% had survived, some of which had been in the surface slump area. The erosion control director who had been tasked with inspection, noted the problems.

Solution: The success criteria included management responses to both of these issues. The bare area management response was to re-treat the area. Since only a slight amount of movement occurred, most of the soil amendment was in place. Soil was moved back into place by hand, some reseeding was done, followed by mulching and irrigation. Since only 120 seedlings survived the winter and a plant census showed that two particular species had the best survival rates (85 and 70%), 75 individuals of those two species were planted and irrigated. When the USFS staff inspection took place 3 weeks later, the area was already showing a robust cover of young green shoots in the re-treatment area and the newly planted seedlings were showing good growth and new buds as well.

The results of this process eliminated the need for the USFS inspection staff to take any sort of action since the responsibility and initiative for action had been taken by ski area staff. Inspection was positive and non-confrontational.

Technical Note 7: Monitoring: Soil nutrient sampling; Cone penetrometer sampling; Cover point monitoring; Soil site characteristics/existing conditions assessment

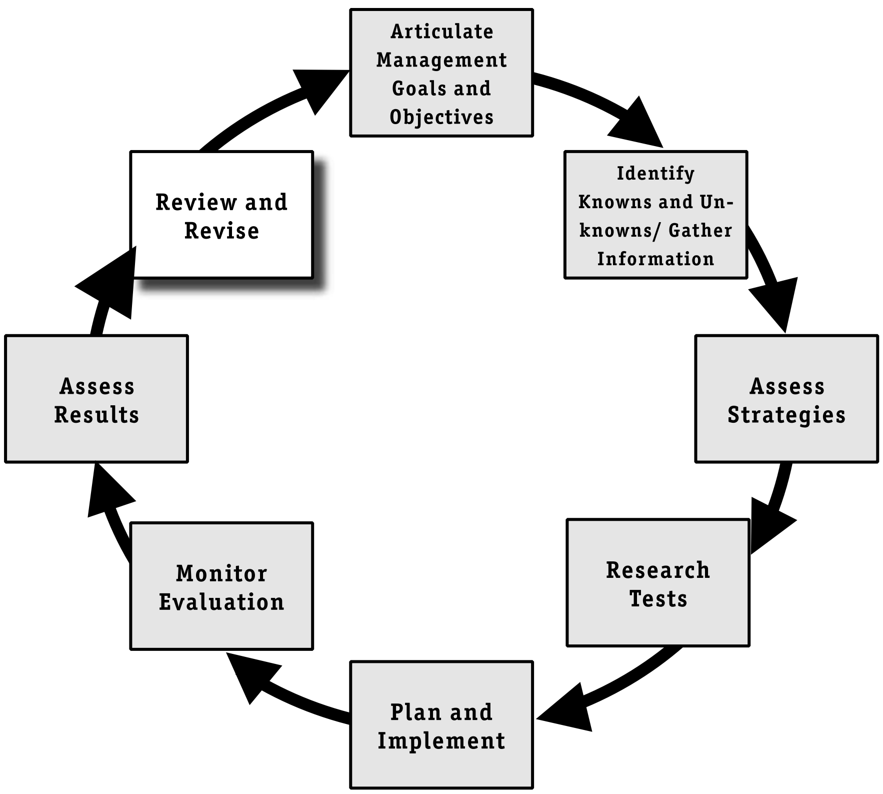
Additional suggestions: Latitude exists to develop and suggest monitoring protocols and procedures that may be less expensive and/or more accurate in determining project function. For instance, cone penetrometer readings may provide more information about site erosion potential than cover point monitoring. Work is needed to determine which monitoring methods are most useful and cost effective.

GUIDING PRINCIPLE 14: FOLLOW-UP TREATMENT

Goals: 1) to address problem areas that fail to meet success criteria so that they can be brought up to acceptable levels; and 2) to input additional resources (water, seed, fertilizer, etc.) that may be needed in subsequent seasons to assure the success of certain treatments.

Description: Small follow-up treatments can reverse problem trends quickly and cost effectively. If left alone, small problems can become a large and expensive problem to repair.

Example: A newly treated area is inspected the following season. A small rill has carried water from above the run and at one point, has resulted in a small rotational failure (mini-landslide). The inspector follows the rill upslope and finds that a waterbar has filled with sediment and breached. The waterbar has a slight level spot, which accumulated sediment, thus causing the breach. The waterbar was re-cut, the rill was hand tilled and re-seeded and the rotational failure was rebuilt, and reseeded. All were irrigated.



Solution: The solution, described in the 'Example' section, while somewhat time consuming, dealt with a relatively small problem. Left untreated, this trend would have resulted in a large gully forming which would have also run across a key service road, requiring reengineering of the road as well as partial rebuilding of the run. A relatively small amount of work precluded a great deal of work later.

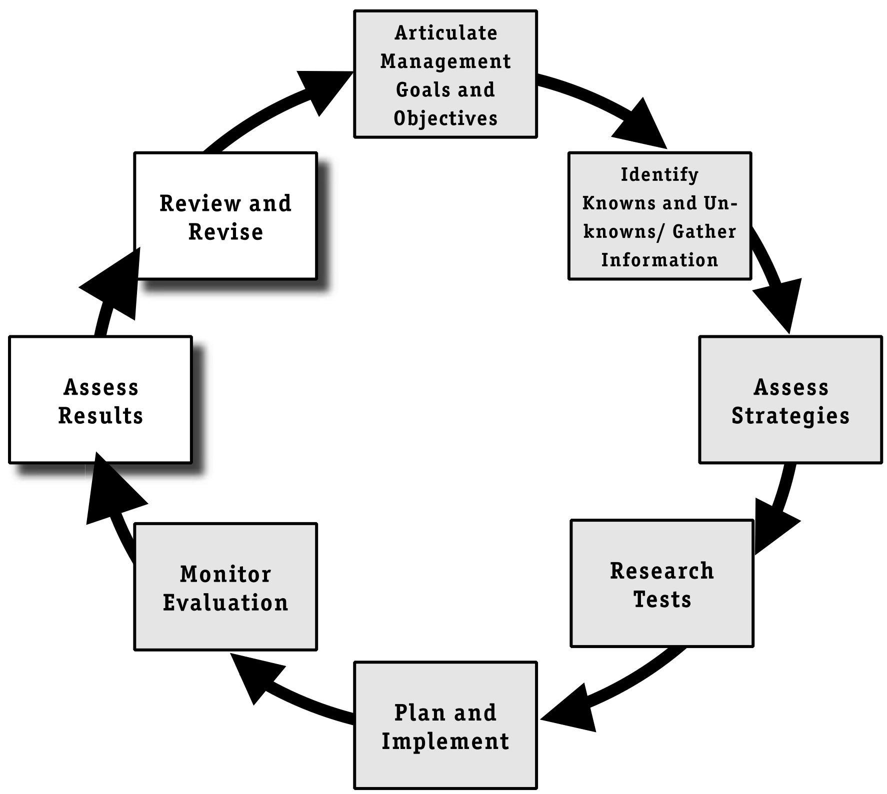
Additional suggestions: Follow-up treatment includes standard post-project treatments such as supplemental irrigation and fertilization. Most projects are more cost effective where follow-up treatment such as these are minimized and/or employed for as short a time as possible. If an area needs ongoing irrigation or fertilization to maintain 'success', once expensive follow-up treatments are ended, the site is likely to revert to low plant cover and high run-off potential.

GUIDING PRINCIPLE 15: FUTURE PROJECT IMPROVEMENT

Goal: To assess information from existing projects to improve future projects.

Description: When gathering information from existing projects (see GP 7 & 13), that information, if processed and assessed properly, can enhance future projects. This is especially true if experimental elements have been included. Treatments that worked well can be replicated and modified. Treatments that haven't worked as expected can be eliminated or more radically adjusted for future projects.

Example: Hydroseeding and fertilization with ammonium phosphate or ammonium nitrate (16-20-0) had been used in the Lake Tahoe Basin for over twenty years. No goals, success criteria or monitoring was done on those projects. Current monitoring is showing that most projects on drastically disturbed slopes did not limit erosion to acceptable levels.



Solution: Monitoring linked to appropriate success criteria would have allowed project inspectors to realize that hydroseed and chemical fertilizer treatment weren't producing desired plant cover or sediment source control. We would be much further along in the process of ensuring sediment source control in the Tahoe Basin and other alpine environments.

Additional suggestions: There is no existing formula to take monitoring data and create a direct improvement mechanism. It is most useful to try to eliminate what doesn't work and improve on what does.

Guiding Principle 16: Information Sharing

Goal: ***To share useful project information so that other project planners, implementers, and assessment personnel can improve their practices.***

Description: This step assumes that environmental improvement should be universally beneficial and not limited by proprietary processes. Where information can be shared effectively, the information benefits the environment and others doing similar work. This commitment to share information brought the CAREC team together.

Information distribution can take many forms such as web-based distribution, professional society or group meetings, newsletters and so on. If tracked efficiently, information sharing improves the state-of-the-art in sediment source control, thus benefiting users environmentally and economically.

Example: A ski area employee has just been appointed head of erosion control. Reading a trade publication, she begins to assume that hydroseeding is the most powerful process for erosion control on the planet. A magazine article shows two people and a car, all had been hydroseeded, and were completely covered in grass. She contracts with a local hydroseed specialist to seed an eroding run for the sum of $2000/acre, a relatively reasonable sum. The following season, nothing is growing and the new manager must defend her job. Photos from the magazine article are not convincing!

Solution: The manager goes onto the web to a newly developed CAREC web site that lists local results of a number of erosion control field test applications. She sees that in high alpine situations on her soils, hydroseeding produced inconsistent results. However, a more expensive 'full soil and vegetation restoration treatment' had been shown to completely eliminate runoff and thus erosion, for the 3 monitoring seasons to date. She quickly calculated how many times she would have to hydroseed to equal the cost of the soil treatment. She reasoned that four hydroseed treatments would roughly equal one full soil treatment, which she implemented. This information assured her of success and since the following season the results were irrefutable, solidified her job as well.

Additional suggestions: Information sharing is challenging since most practitioners are extremely busy getting their normal work accomplished. However, when information sharing is efficient, work will be more effective since practitioners will not have to treat the same site multiple times.

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